GE Energy Infrastructure

Data Requirements for Wind & Solar Integration Studies

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UWIG Solar Integration User Group Meeting
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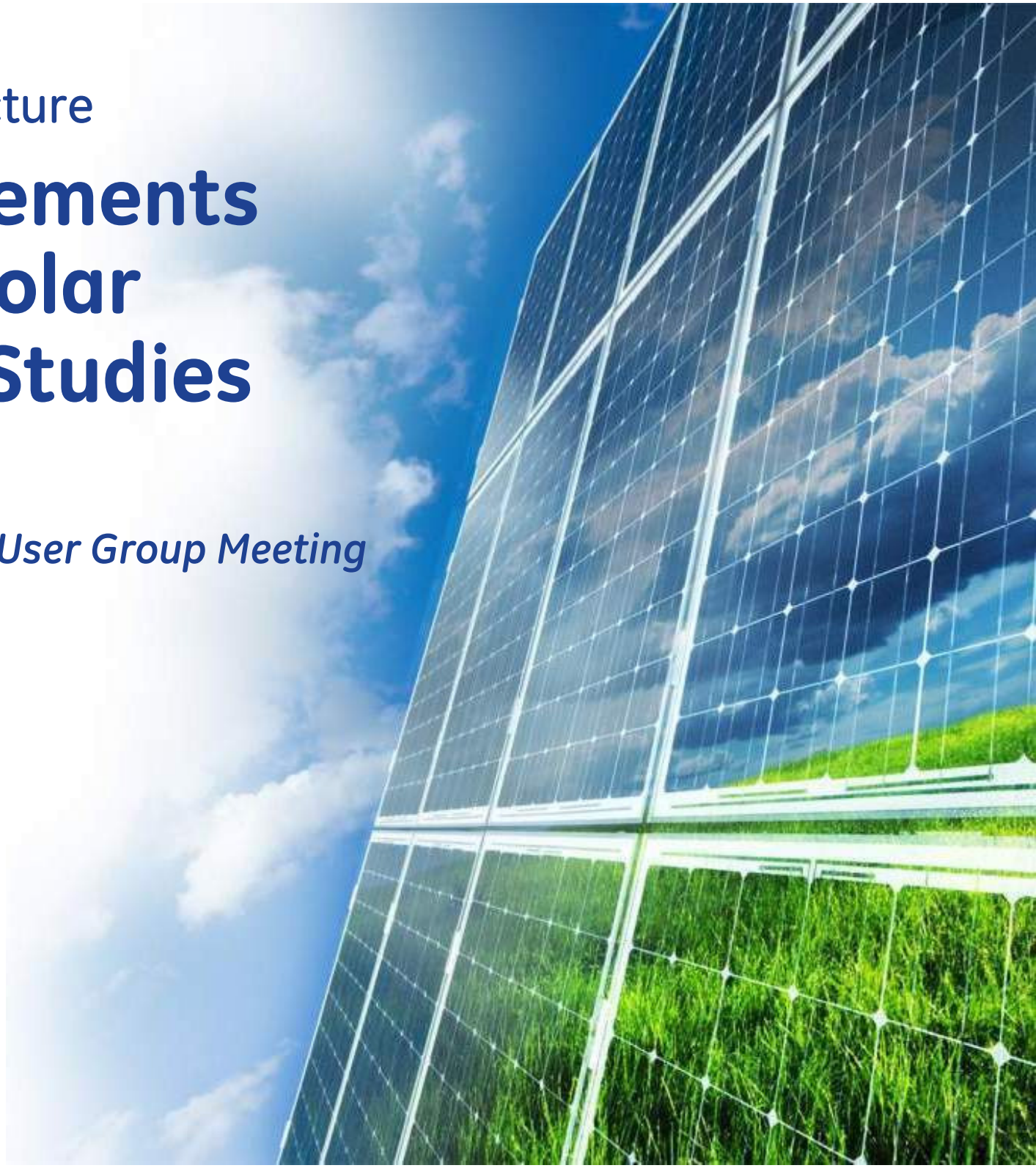
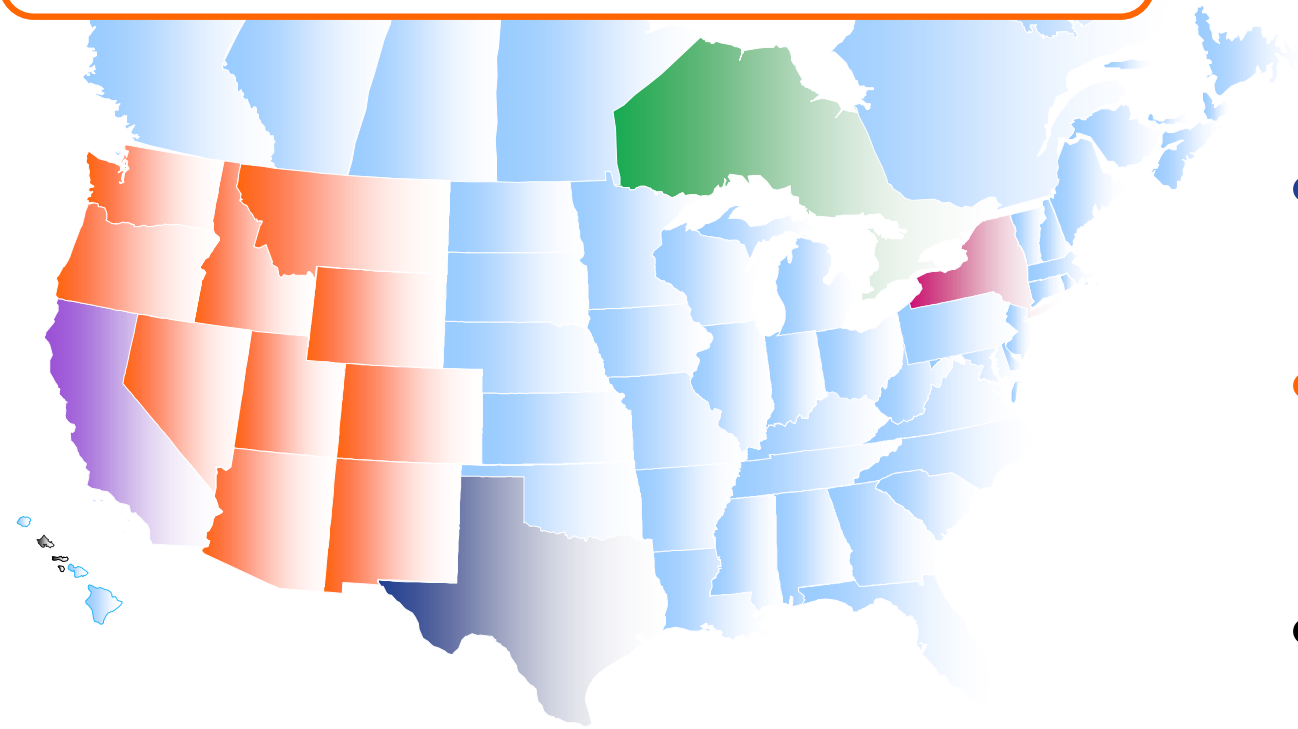
imagination at work



Renewables Studies by GE

These studies were commissioned by the Energy Commissions, ISOs, & utilities…

- Examining the Feasibility of 100+ GW of new wind & other renewable resources
- Considering Operability, Costs, Emissions, Transmission Constraints, Forecasting



- 2004 New York:
  - 3 GW Wind
  - 10% of Peak Load
  - 4% of Energy
- 2005 Ontario:
  - 15 GW Wind
  - 50% Peak Load
  - 30% Energy
- 2006 California:
  - 13 GW Wind & 5GW Bio/Geo
  - 3 GW Solar
  - 26% Peak Load
  - 15% Energy (33% total)
- 2007 Texas:
  - 15 GW Wind
  - 25% Peak Load
  - 17% Energy
- 2009 Western region:
  - 72 GW Wind
  - 15 GW Solar
  - 50% Peak Load
  - 27% Energy
- 2010 Oahu:
  - 500 MW Wind
  - 100 MW Solar
  - 50% Peak Load
  - 25% Energy

Mostly focused on wind… emerging interest in solar

Typical Study Objectives

Evaluate grid operation with increasing levels of variable generation

- Target levels of wind and solar penetration

Identify and quantify system performance and operation problems

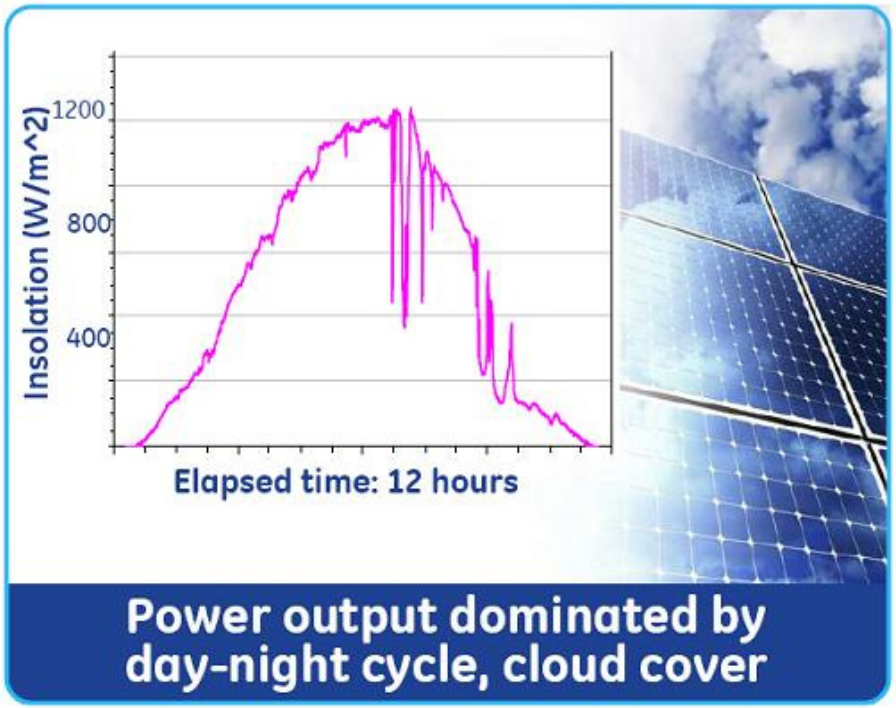
- Load following, regulation, minimum load, wind curtailment levels, impact on variable cost, etc.

Identify and evaluate possible mitigation methods

- Reduce wind curtailment, improve thermal unit efficiency, maintain reliability, etc.

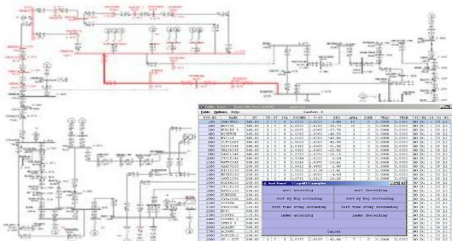
PV Output Variations

- Predictable daily curve, often "chopped up" by unpredictable downward variations
- Impact of ratio of PV MW rating to feeder load
  - Small – PV variability acts like a modifier to the load curve
  - Large – PV variability has significant voltage impact
- Fast voltage variations is primary local impact (cloud shadow passage)
- Power variation of less significance (until penetration is high)

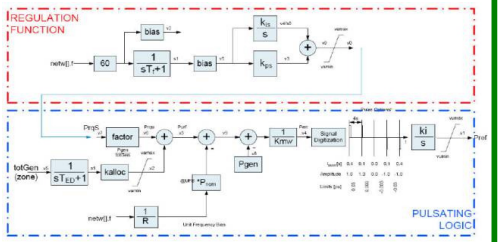


GE Power Systems Modeling Tools

Positive Sequence Load Flow (GE PSLF)



Long-term Dynamic Simulations (AGC)

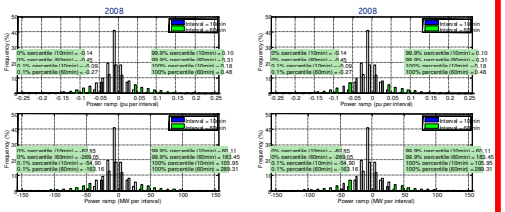


Tools are used together to assess the challenges & provide information needed for operations & planning.

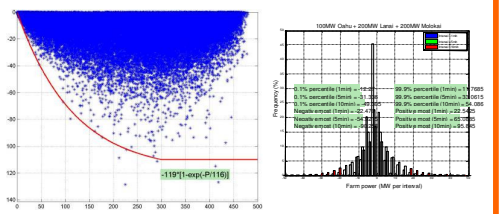
1 sec | 1 min | 10 min | 1 hr | 1 day | 1 wk

- Voltage Support
- Inertia
- Governor Response
- AGC Regulation
- Economic Dispatch
- Planning

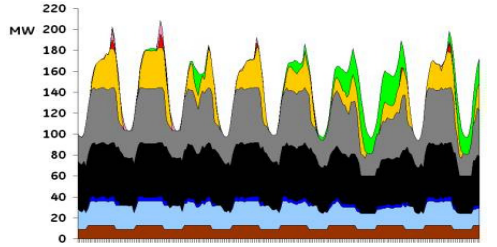
Statistical Wind Power Variability Assessments



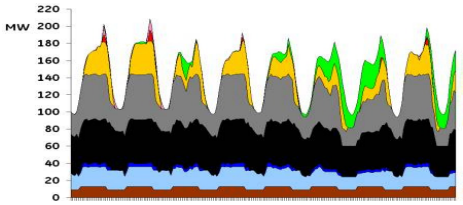
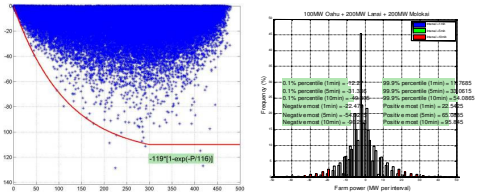
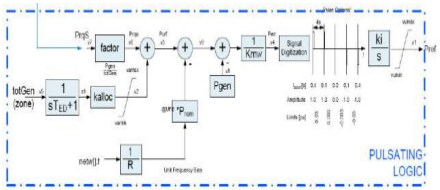
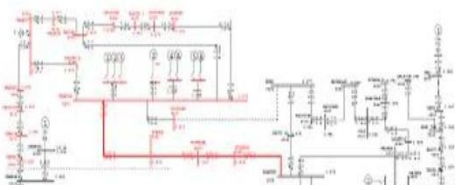
Interhour Renewables Variability Analysis



Multi-Area Production Simulation (GE MAPS)



Mapping Tools to Requirements

Multi-Area Production Simulation (GE MAPS)	Inter-hour Variability Analysis	Long-term Dynamic Simulations (Auto Gen Control)	Positive Sequence Load Flow (GE PSLF)
			
Unit commitment/ dispatch, representing operating rules, benchmarked against system operation.	**Sub-hourly wind/solar/load changes with respect to reserve, based on commitment and dispatch.**	**Frequency analysis, including governors and AGC response. Initialized from MAPS and driven by major wind/solar events.**	**Full Transmission model for voltage & stability performance, governor response, contingency analysis.**
Hourly results for 1yr	**10min results for 1yr**	**1sec results for one 1hr**	**1ms results for 1min**

Quantify energy production, variable cost, wind power curtailment, emissions, etc for each scenario to assess…
• Wind/solar delivered
• Unit commitment
• Variable cost
• Emissions, etc
	Quantify reserve violations, fast starts & load shed events caused by sub-hourly wind/solar/load changes…
	• Assess reserve requirements
	• Assess fast-start events
	• Select windows for further analysis
		Quantify frequency performance during wind/solar variability events and wind ramp events…
		• Reserve requirements
		• Types of regulating units,
		• Benefit of increasing ramp rates
			Quantify system stability performance during contingencies…
			• Wind/solar plant requirements (freq control, LVRT, voltage control)
			• System contingencies
			  • Generator trip
			  • Load rejection
			  • Other

Solar-Integration Studies

What are some the questions being asked?

- What is the relative impact of solar energy production from distributed PV and centralized PV on system balancing?
- What is an appropriate level of up regulating reserve that may be needed to address short-timescale solar variability?
- What is the accuracy and reliability of solar forecasting for unit commitment (hours to days ahead)?
- What is the impact of solar power variability on thermal unit maneuvering?
- What are the solar-related contingencies that can be used for system planning?

Results can be used to shape requirements for distributed and centralized solar interconnections

Solar-Integration Studies

What is the difference between T and D?

Transmission-level

Aggregate impact of wind/solar (power/frequency, regulation, longer-timescale)

- One year of 10-min, time-synchronized, wind/solar power & forecast by substation is needed.

Distribution-level

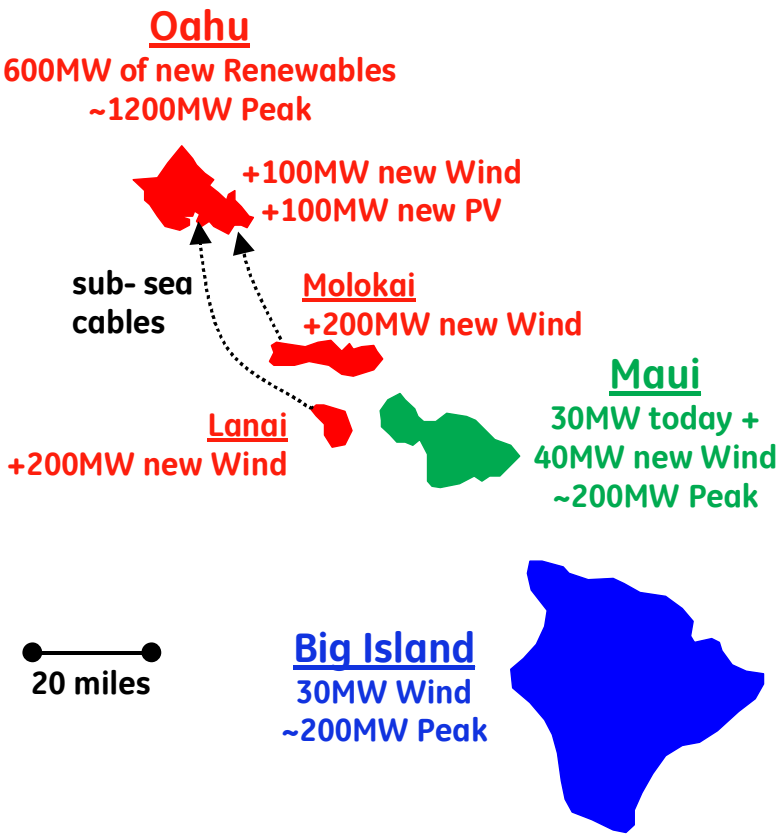
Local interconnection of wind/solar (voltage, protection, shorter-timescale).

- One year of <1min, time-synchronized, wind/solar power by site.

Accurate temporal & spatial relationships are very important for systems with few wind/solar plants and high wind & solar penetration. Need to look at both distributed & central PV plants.

High Penetration Renewables in Hawaii

It is happening in Hawaii



Wind Penetration

Installed Wind Capacity / (Min Load + Export Capacity)

West Denmark	~58%
Schleswig Holstein (Germany)	~44%
Gotland (Sweden)	~40%
Ireland	~38%

In Hawaii...	
Maui (today)	~38%
Big Island (today)	~39%
Oahu (future)	~78%

*source of data for regions other than Hawaii from "Wind Power Integration in EirGrid Operating Experience", Jody Dillon, Renewables Integration Group, presented at the UWIG conference in Fort Worth, Texas April 2008.

Hawaiian Electric Company

Hawaii Natural Energy Institute

imagination at work

Details of these systems matter a lot.. High wind/solar penetration and few wind/solar plants... Highly accurate temporal & spatial relationships are important

Wind & Solar Data for Hawaii Studies
What data were provided?

Wind

- 10-min wind power, speed & forecast (different timeframes) from AWS Truewind
- 1min & 2sec wind power & speed also provided by AWS Truewind
  - Used to compared short-timescale wind variability (1min, 5min, 10min) to thermal unit ramp rate capability.

Solar

- 10-min solar power data provided by NREL (Debbie Lew/Ray George) based on existing sites.
- 2-sec data also provided for select windows of interest (high variability)

Wind & Solar Data for Hawaii Studies

What was done with the data?

Statistical Analysis

- Multiple time periods (Hourly, 5-minute, 1-minute)
- Assess accuracy of data as compared to historical variability

Production Cost Simulation with GE MAPS

- Hour-by-hour simulation of grid operations for an entire year

Inter-hour Simulations

- Screen through a year of production cost results assessing 10-min changes in wind/solar/load within each hour to select most challenging windows (ramp rate / up reserve constrained)

Long-term Dynamic Simulations with GE PSLF

- Second-by-second time-sequenced response of thermal units to governor response and AGC requests for specific hours.

Results of these studies rely on the accuracy of wind and solar data across many timescales.

Solar Integration Studies
Data we may need in the future?

- Solar plant size, type, substation location for each plant
- One year (maybe more)
  - 10min time-synchronized power data for each of the sites. 10-minute resolution has been used effectively in recent wind studies
  - Hourly, day-ahead solar power forecast data
  - Ability to generate wind power data from historical wind speed data. Unclear whether same capability exists for solar from insolation?
- Higher resolution time synchronized solar power data for selected windows (e.g. 1-3 hours) of interest
  - Selected windows screened from longer-term data & system conditions
  - Resolution of 1-2 second sampling needed for small or granular systems [jury is out on what "small or granular means"]
  - Resolution of 1-2 minute needed for larger system analysis
- Each data must be time synchronized for the future study year(s)
  - Maintain solar/wind/load time and space relationship.